Recent Advances in Infrared Semiconductor based Chemical Sensing Technologies

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Abstract: Recent advances in the development of sensors based on the use of quantum cascade lasers (QCLs) for the sensitive, selective detection, quantification and monitoring of both small and large molecular gas species with resolved and unresolved spectroscopic features respectively will be reported

Recent advances in the development of sensors based on the use of diode and quantum cascade lasers (QCLs) for sensitive, selective detection and quantification of both small and large molecular gas species with resolved and unresolved spectroscopic features respectively will be described . Different spectroscopic techniques have been employed such as laser absorption spectroscopy (LAS), cavity absorption enhancement or photoacoustic spectroscopy. A novel technique called quartz-enhanced photoacoustic spectroscopy (QEPAS), which was first reported by us in 2002 will be emphasized [1,2]. Considerable experimental and analytical progress has been made with QEPAS since 2002. Recently we have investigated the effect of humidity and 2-tube microresonator effects on detection sensitivity of different chemical species, in particular the diameter, length for QEPAS.

QEPAS allows a breakthrough in high immunity to environmental acoustic noise, excellent noise equivalent concentration (ppm to ppt) and dynamic range as well as size, weight and cost. Applications include concentration measurements of single and multiple trace gas species for applications in such diverse fields as environmental monitoring, industrial process control and medical diagnostics [3]. In this presentation we will refer to four examples of real world sensor applications, which include fire and post fire detection in spacecraft habitats [4]**,** CO_2 monitoring in and around sequestration reservoirs, real time monitoring of ammonia concentrations in non-invasive breath analysis and safeguarding nuclear materials (UF_6)**.**

Significant progress has been made in real time ammonia detection of exhaled human breath with both a distributed feedback and tunable external cavity quantum

Fig. 1. Quartz tuning fork based spectrophone with acoustic resonator for signal to noise ratio enhancement.

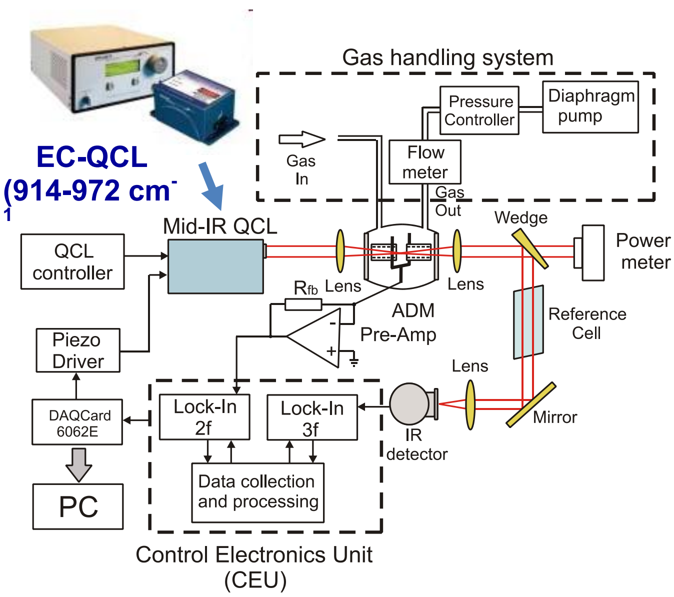

Fig. 2. Real-time breath sensor architecture for ammonia detection.

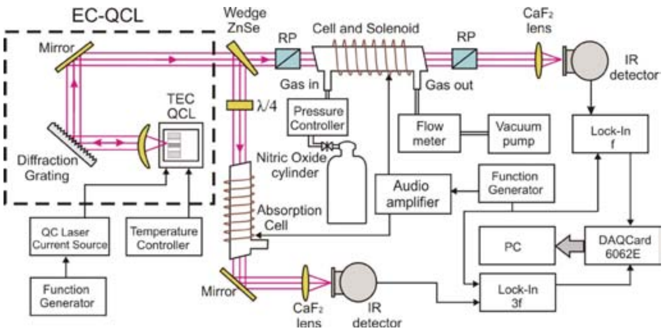

Fig. 3. External Cavity Quantum Cascade Laser based Faraday Rotation Spectrometer for nitric oxide detection.

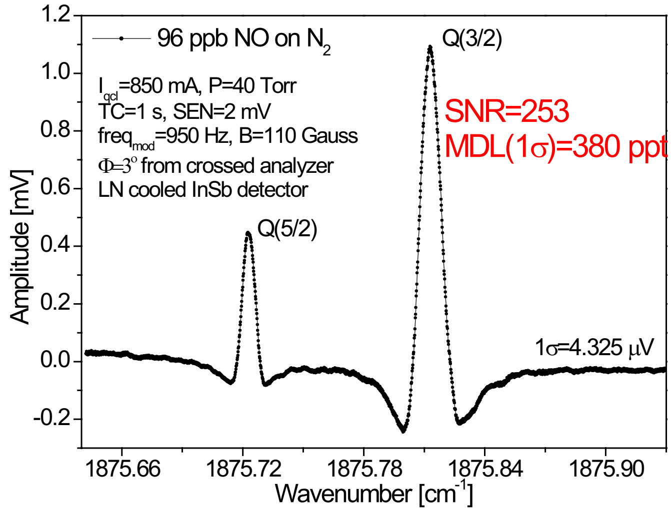

Fig. 4. Faraday rotation spectrum of $Q_{3/2}(3/2)$ and $Q_{3/2}(5/2)$ transitions of NO centered at 1875.8 cm^{-1} meastured for a 96 ppbv in N_2 mixture at 40 Torr. Using liquid nitrogen cooled InSb photodetector. The analyzer angle is 3°, the time constant is 1 second and the modulation is 110 G at 950 Hz.

cascade laser based QEPAS sensor operating at ~ 10.5µm. Ammonia is associated with liver and kidney disorders. Typical concentrations of ammonia in hundreds ppb, whereas elevated levels (> 1 ppmv) indicate significant pathology.

A transportable Faraday rotation spectroscopic system based on a tunable external cavity QCL has been developed for ultra sensitive detection of nitric oxide (NO). A broadly tunable laser source allows targeting the optimum Q(3/2) molecular transition at 1875.81 cm^{-1} in the Q branch of the NO fundamental band. For an active optical path of 44 cm and 1sec lock-in time constant the minimum NO detection limits (1σ) of 0.38 ppbv are obtained using a liquid nitrogen cooled indium-antimonide photodetector.

State-of-the -art semiconductor laser technology based on infrared absorption spectroscopy offers the opportunity to detect both in situ and remotely trace gases of specific interest to the International Atomic Energy Agency (IAEA), Vienna charged with the detection and verification of nuclear materials and activities on a global basis. Laser absorption spectroscopy (LAS) has been proposed as a spectroscopic technique that is capable of an accurate uranium enrichment determination of UF_6 samples [5] The current status of development of a cw, room temperature DFB QCL based spectroscopic source operating at 7.74 µm (1291 cm^{-1}) for use in field deployable sensor plaform will be described.

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